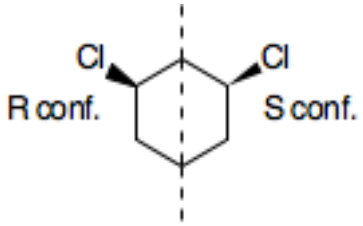
Meso Compounds

What is a Meso Compound?

A meso compound is a molecule with multiple stereocenters that is superimposable on its mirror image. These particular traits lead to specific qualities that meso compounds do not share with most other stereoisomers.

One such quality is the internal mirror plane. All meso compounds have something called an internal mirror plane. This internal mirror plane is simply a line of symmetry that bisects (cuts in half) the molecule. Each half is a mirror image of the other half. Here is an example of a meso compound and its internal mirror plane:



In the molecule above, the left and right sides are mirror images of each other and are symmetric about the internal mirror plane (the dashed line in the middle). Remember, however, that each half must contain a stereocenter in order to be a meso compound. Any molecule can have an internal mirror plane, but meso compounds must also be stereoisomers, and stereoisomers must have a stereocenter (i.e. an atom in the molecule that has three or more different attachments). Meso compounds must have a minimum of two stereocenters, with at least one on each side of the internal mirror plane. These stereocenters must also have different absolute configurations. If both of the stereocenters have the same absolute configurations, then each half would no longer be a mirror image of the other half and the compound would no longer be a meso compound, but instead another stereoisomer.

These opposing absolute configurations bring up another interesting quality of meso compounds. Since meso compounds are superimposable on their mirror images, they are considered achiral (chiral molecules, on the other hand, are not superimposable on their mirror images). Achiral molecules, in turn, are considered optically inactive. Meso compounds are optically inactive due to these differing absolute configurations on the opposing stereocenters. Because each side has different stereochemistry, the optical characteristics of each side cancel each other out. Stereocenters on one half of the molecule will turn plane-polarized light one way, and the stereocenters on the other half of the molecule will turn plane-polarized light in the opposite direction, resulting in non-rotated light. Thus, meso compounds cannot be assigned with either dextrorotatory (+) or levorotatory (-) designations.

A meso compound is achiral so cannot have an enantiomer. When a molecule is superimposable on its mirror image, then that molecule and the mirror image are merely the same molecule.

How Do You Identify Meso Compounds?

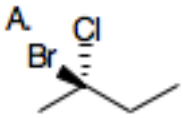
You can identify meso compounds through the following easy steps:

Meso Compound Check List

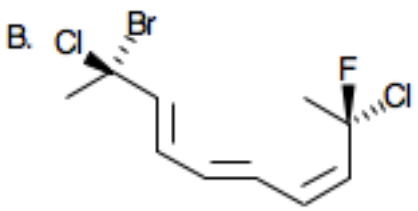
1. **Identify how many stereocenters the molecule contains.**
    a. A meso compound is a stereoisomer and, thus, by default must have a stereocenter. Meso compounds require at least two stereocenters. A compound with only one stereocenter cannot be considered a meso compound as it would not be achiral and would not have another stereocenter to oppose its optical behavior.
2. **See if the molecule has an internal mirror plane.**
    a. Any molecule can have stereoisomers, but not all have internal mirror planes. The mirror plane should bisect the molecule.
3. **Ensure that both halves are in fact mirror images of each other.**
    a. The meso compound must be symmetric about the internal mirror plane. Each opposing stereocenter must have differing absolute configurations and the attachments on each stereocenter must be the same. If the opposing stereocenters have the same absolute configurations or the attachments on either side are different, then one half will not be a mirror image of the other half.

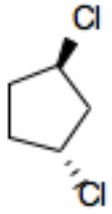
If your molecule fulfills all three requirements (has at least two stereocenters, contains an internal mirror plane, and is totally symmetric about that mirror pane/each half is a mirror image of the other half), then your molecule is in fact a meso compound! A few examples of applying this process are below:

Example A: Is molecule A a meso compound? Let's go through the checklist. 1. Does molecule A have at least two stereocenters? No, molecule A only has one stereocenter and, thus, is not a meso compound.



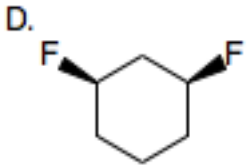
Example B: Is molecule B a meso compound? Let's go through the checklist. 1. Does molecule B have at least two stereocenters? Yes. 2. Does molecule B have an internal mirror plane that bisects the molecule? No, molecule B does not have an internal mirror plane that bisects the molecule. This molecule is haphazardly shaped and cannot be evenly divided into halves, and, thus, is not a meso compound.



C. 

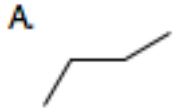
Example C: Is molecule C a meso compound? Let's go through the checklist. 1. Does molecule C have at least two stereocenters? Yes. 2. Does molecule C have an internal mirror plane that bisects the molecule? Yes. 3. Are both halves of the mirror plane mirror images of each other? No. While each stereocenter has the same attachments, both have the same absolute configurations. Therefore, molecule C is not a meso compound.

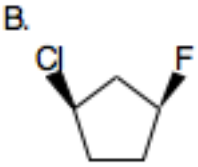
Example D: Is molecule D a meso compound? Let's go through the checklist. 1. Does molecule D have at least two stereocenters? Yes. 2. Does molecule D have an internal mirror plane that bisects the molecule? Yes. 3. Are both halves of the mirror plane mirror images of each other? Yes. The left stereocenter has an absolute configuration of R and the right stereocenter has an absolute configuration of S. Thus, molecule D fulfills all of the requirements on the checklist and is in fact a meso compound!

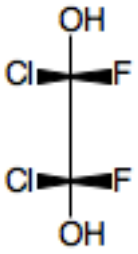
D. 

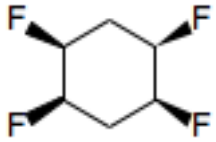
Exercises

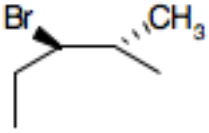
1. Which of the following structures are meso compounds?

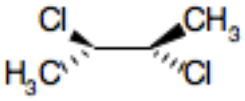
A. 

B. 

C. 

D. 

E. 

F. 

2. A compound has four stereocenters and multiple stereoisomers. If one of those stereoisomers is a meso compound, how many total stereoisomers does this compound have?

3. How can you tell if a meso compound is dextrorotatory (+) or levorotatory (-)?

Answers to Exercises

1. C, D, and F are meso compounds as they fulfill all three requirements on the checklist (If F is giving you trouble, look at it this way: if you rotate F along the C2–C3 sigma bond, you can see that one side is in fact the mirror image of the other side). A is not a meso compound as it has no stereocenters. B is not a meso compound as while it does have two stereocenters and has an internal mirror plane that bisects the molecule. Its two opposing stereocenters have different attachments. E is not a meso compound as it does not have two stereocenters and has no internal mirror plane that bisects it.

2. A compound that has four stereocenters would normally have 16 stereoisomers (total number of stereoisomers = 2^N where N = number of stereocenters). But since one of those isomers is a meso compound, its enantiomer is the same as the meso compound. Therefore this compound only has 16 - 1 = 15 stereoisomers in total.

3. Meso compounds are neither dextrorotatory nor levorotatory as they are achiral and therefore optically inactive. The opposing types of stereochemistry on both halves cancel out each other's optical effects.